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Announcement of Annual Meeting ..... Inside Front Cover

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RESULTS OF FERTILIZER TRIALS ON POTATOES IN THE SAN LUIS VALLEY

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(Accepted for publication, June 8, 1950)

The results of fertilizer trials with potatoes in the San Luis Valley of Colorado have been variable and some of them conflicting. This variation has been believed to be due to the soil heterogeneity and the variation in moisture between years (3)[5]. Since more fertilizer is being used each year it is important to know the fertilizer analysis best suited, and also the amount per acre which produces the most economical yields and best quality including grade, tuber color and specific gravity.

Procedure

To overcome some of the difficulties encountered by previous workers it was decided that larger plots permanently marked so that the same fertilizer could be put on the same plot of ground for a period of years might be

[1] Horticulturist, [2] Agronomist and [3] Chief Horticulturist.

[4] The authors gladly acknowledge the assistance of C. W. Frutchey, Extension Potato Specialist; W. Frank McGee, Superintendent of the San Luis Valley Branch Station, and Professor Andrew G. Clark, Professor of Mathematics, for technical assistance; and Anaconda Copper Company, Colorado Fuel & Iron Corporation and the American Potash Institute for supplying materials.

[5] Refers to literature cited. Sci. Ser. No. 328.

advantageous. It was also reasoned that if the soil heterogeneity within small areas was great large plots, or a great many replications with small plots, might add to the precision as well as make the results more widely applicable. Since the larger plots are more easily managed than a great many small ones it was decided to use the larger plots.

Twelve treatments were randomly arranged in blocks and replicated five times. The individual plots were 4 rows wide and 100 feet long. Only the center two rows in each plot were harvested for data, but the area harvested was still twice as large and the total plot area four times as large as that of the earlier workers (3). The rows were 34 inches apart and the seed pieces in the rows were planted 12 inches apart. The fertilizer was applied uniformly at planting time in two bands about two inches to each side and two inches below the seed pieces.

The plots were fertilized and planted about the 14th of May and harvested about the 18th of September for four consecutive years. During the growing season the cultural practices common to the area were used. Prior to the experiment the land had been planted to oats and sweet clover which was pastured off by sheep.

At the outset of the experiment the ground was chiseled to a depth of approximately two feet. The chisel points were about two feet apart and were pulled through the field lengthwise and crosswise so that the soil was cut into small areas of approximately four square feet. The plots were chiseled each year thereafter to a depth of about sixteen inches instead of being plowed, to minimize the movement of fertilizer from one plot to another.

The tubers were sorted and sized within a week after harvest and samples of 50 tubers were taken from each plot for color and specific gravity measurements. These samples were stored at 40°F. until the measurements could be made which was within two months after harvest.

Color measurements were made on the 50-tuber samples with the disc colorimeter described by Sparks (5) and specific gravity measurements were made on the same 50-tuber samples by Archimedes' principle (6).

The data from the permanent plots were analysed according to the method of Immer for permanent plot analysis (1), whereas the data from the farmer's plots were analysed by the method for complex experiments given by Leonard and Clark (2).

Procedures Followed on Farmer's Fields[6]

The results obtained from the permanent fertilizer trial on the San Luis Valley Branch Station were in such close agreement the first two years that experiments of nine treatments and six replications were applied on ten different potato grower's farms the following year (1948) to test the applicability

[6] Cooperative with C. W. Frutchey, Extension Potato Specialist

of the station results. It was decided that the method of applying fertilizer and the size of the plots would be the same as those used on the Branch Station. The treatments were randomly arranged in blocks and replicated six times on each farm. This same type of experiment was conducted in 1949 but the rates of application of fertilizer were higher and the size of the plots was cut to two rows in width which eliminated the buffer rows. The total yield was the only factor considered and this was obtained by weighing the tubers from the two center rows in each plot in 1948, and both rows in 1949.

Results and Discussion[7,8]

The detailed results of the effect of fertilizers, when applied to the same soil for four consecutive years, on the yield and grade of Red McClure potatoes are shown in table 1. The mean results for the four years are shown graphically in figure 1 and these will be used primarily as a basis for discussion.

In general, it can be seen (Figure 1) that as the amount of N and P_2O_5

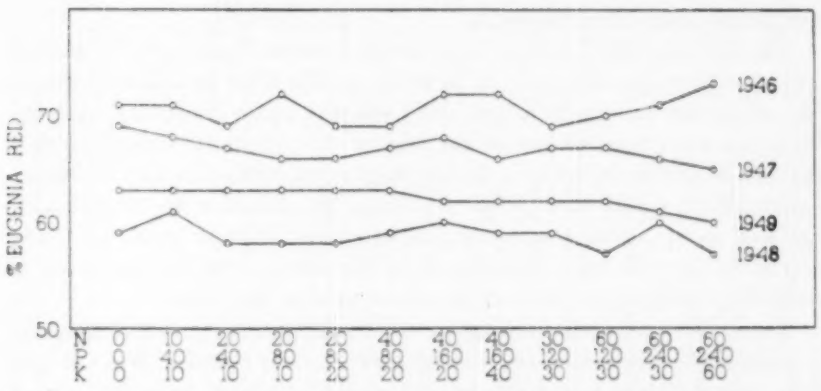

Fig. 1—The effect of various fertilizers on the yield and grade of Red McClure potatoes in the San Luis Valley.
10-40-10, *etc.*, does not mean the analysis but the actual pounds of N, P_2O_5 and K_2O applied per acre.)
1946-1949.

increased, the total yield per acre increased. As the yield per acre increased the yield of U. S. No. 1 tubers above 2 inches in diameter also increased as did the yield of U. S. No. 2's and culls; however, there was a slight tendency for the yield of tubers under 2 inches in diameter to decrease. When the yield per acre of U. S. No. 1 potatoes above 2 inches in diameter and yield per acre

[7] In this paper 10-40-10, *etc.*, does not mean the analysis but the actual pounds of N, P_2O_5 and K_2O applied per acre.

[8] All differences considered are large enough to be significant at the 5 per cent level or greater.

of U. S. No. 2's and culls were converted to percentages of the total it was found that there were differences in grade caused by the different fertilizer treatments. However, these differences were so small they were of little or no practical significance when the increase in yield due to any particular treatment was taken into consideration (Table 1). Since the data were on a weight, and not on a tuber basis, it is quite possible that the increased weight of lower grade tubers was caused by the fact that the individual tubers from the high yielding plots were larger than those from the low yielding plots.

At the time this work was undertaken an unfertilized treatment was included in the treatments to serve as a basis for determining fertilizer response but since the response to commercial fertilizers was general and of high magnitude it was decided to use treatment 40-160-20 as a check. This treatment produced consistently high yields both at the Branch Station and on farmer's fields. From figure 1 it can be seen that any treatment which did not produce an average yield of 298 sacks per acre yielded significantly less than the treatment consisting of 40 pounds of N, 160 pounds of P_2O_5 and 20 pounds of K_2O per acre used as a check. None of the treatments used yielded significantly more than the check.

Considerable differences in yield occurred on the same piece of ground between different growing seasons, as shown in table 1, for no apparent reason. The interaction between fertilizers and years was highly significant. Had the treatments receiving 240 pounds per acre of P_2O_5 produced a yield the first year about equal to the mean of the last three years, both treatments 60-240-30 and 60-240-60 would have yielded more than the treatment 40-160-20 which was used as the check. Conversely, had treatment 20-80-10 produced yields during the first two years equal to about the mean of the last two years it would have yielded less than the treatment used as the check.

The value of potash in the fertilizer was doubtful as is revealed in figure 1. It is regrettable that treatments without K_2O were not included. When N and P_2O_5 were held constant at 20 and 80 pounds per acre, respectively, and K_2O was increased from 10 to 20 pounds per acre a non-significant decrease in yield resulted. When N and P_2O_5 were held at 40 and 160 pounds per acre, respectively, and K_2O was increased from 20 to 40 pounds per acre, a very slight decrease in yield apparently resulted from the increased potash. When N and P_2O_5 were held at 60 and 240 pounds per acre, respectively, and K_2O was increased from 30 to 60 pounds per acre, the yield was essentially unchanged.

The partial correlation coefficients between N and yield, P_2O_5 and yield and K_2O and yield were determined using the four-year means of the twelve treatments. The partial correlation coefficient between N and yield was 0.402 which is significant at odds of 4:1. Ordinarily such a value would not be given much credence but it is relatively high considering the limited number of

TABLE 1.—*The effect of various fertilizers on the yield and grade of Red McClure potatoes in the San Luis Valley 1946-1949.*

	Fertilizer Added, Lbs. Per Acre			1946			1947			1948			1949			4 Year Mean		
	N	P_2O_5	K_2O	Total Yield 100 Lb. Sacks Acre	2 in. and Over Per cent	2's and Culls Per cent	Total Yield 100 Lb. Sacks Acre	2 in. and Over Per cent	2's and Culls Per cent	Total Yield 100 Lb. Sacks Acre	2 in. and Over Per cent	2's and Culls Per cent	Total Yield 100 Lb. Sacks Acre	2 in. and Over Per cent	2's and Culls Per cent	Total Yield 100 Lb. Sacks Acre	2 in. and Over Per cent	2's and Culls Per cent
1.	0	0	0	236	86.1	8.3	221	79.2	7.6	186	82.3	7.7	178	83.1	1.8	205	82.7	6.4
2.	10	40	10	283	87.4	10.5	244	81.6	9.4	233	80.5	8.4	253	88.9	3.3	253	84.5	7.9
3.	20	40	10	274	87.1	8.3	259	82.3	10.2	262	84.8	5.8	250	88.0	3.0	261	85.6	6.8
4.	20	80	10	320	89.2	12.0	324	83.0	9.9	262	82.2	7.6	291	90.0	3.0	299	86.1	8.1
5.	20	80	20	279	89.1	11.6	269	82.9	8.7	270	84.1	6.1	260	88.1	3.0	270	86.1	7.4
6.	40	80	20	301	88.4	11.1	311	83.9	8.2	298	85.0	6.3	276	89.3	2.7	297	86.7	7.1
7.	40	160	20	319	89.2	13.7	323	83.2	10.0	336	85.1	7.1	343	89.4	4.5	330	86.7	8.8
8.	40	160	40	341	89.9	14.4	346	80.6	11.9	295	83.6	6.7	314	89.8	3.7	324	86.0	9.2
9.	30	120	30	332	90.1	14.0	330	80.8	12.2	272	82.8	7.0	297	89.6	3.1	308	85.8	9.1
10.	60	120	30	302	88.4	11.3	351	83.3	9.8	320	80.1	9.5	326	88.7	3.8	325	85.1	8.6
11.	60	240	30	315	89.0	12.5	362	82.3	10.5	353	83.5	7.3	265	90.3	3.3	349	86.3	8.4
13.	60	240	60	335	89.2	14.2	355	82.4	11.1	355	81.5	9.4	348	88.9	4.0	351	85.5	9.7
			Mean	302	88.6	11.8	309	82.1	10.0	287	83.0	7.4	292	88.7	3.3	298	85.6	8.1
L.S.D. Treatments within and between years—			5 Per cent =	50.2			4.0	3.7										
			1 Per cent =	67.1			5.3	4.9										
L.S.D. Years—			5 Per cent =	11.14			.9	1.1										
			1 Per cent =	14.67			1.1	1.4										
L.S.D. Means of treatments for four years—			5 Per cent =	32.4			2.0	1.9										
			1 Per cent =	43.3			2.6	2.5										

*Figures for U. S. No. 2's include only growth crack and misshapes and no mechanical damages.

observations used in its determination. The partial correlation coefficient between P_2O_5 and yield (0.696) exceeded the 1 per cent point and the partial correlation coefficient between K_2O and yield was 0.068 or almost *nil*.

It appears from table 1 that there was a general tendency for yields to decrease during the four-year period on the plots receiving the low rates of fertilizer and a tendency for the plots receiving the high rates of fertilizer to maintain and possibly even increase production but contradictory examples are apparent.

Fertilizer Effect on Specific Gravity

The effect of the fertilizers on the specific gravity of the potatoes was non-significant at odds of 19:1. The effect of years was highly significant indicating that the influence of the climatic conditions during the growing season caused greater differences in specific gravity than the fertilizer treatments used even though an attempt was made to reduce the influence of these factors to a minimum by harvesting and planting on the same date each year (Fig. 2).

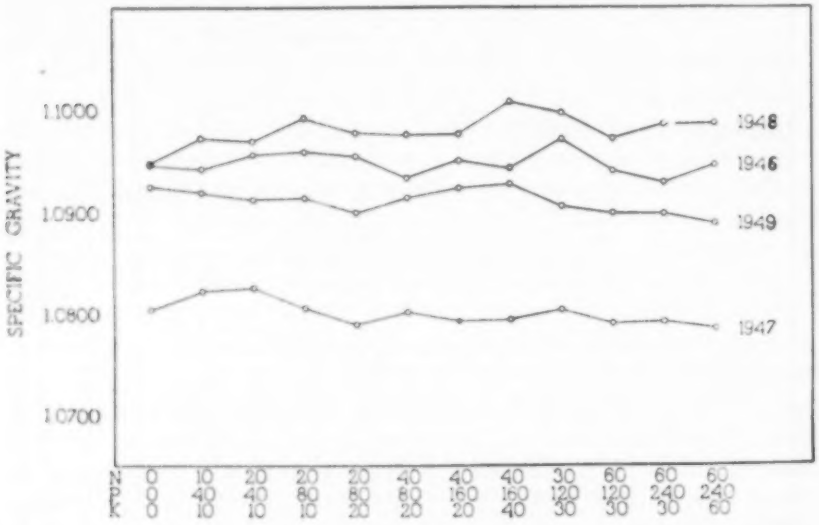

Fig. 2—The effect of fertilizers on the specific gravity of Red McClure potatoes in the San Luis Valley. (10-40-10, *etc.*, does not mean the analysis but the actual pounds of N, P_2O_5 and K_2O applied per acre.) 1946-1949
L. S. D. years— 1 Per cent = 0.001

Fertilizer Effect on Tuber Color

The effect of the fertilizer treatments on tuber color was non significant at odds of 19:1. The year effect was highly significant indicating a possible climatic or maturity effect on tuber color (Fig. 3).

Results of Fertilizer Trials on Farmer's Fields

The results obtained from this experiment in 1948 and 1949 corroborate the results obtained at the San Luis Valley Branch Station regardless of soil type or previous fertilizer and cropping practices. The total yield on the different farms in one hundred pound sacks per acre varied from 188 to 341 during the two-year period. Some of these differences were no doubt due to

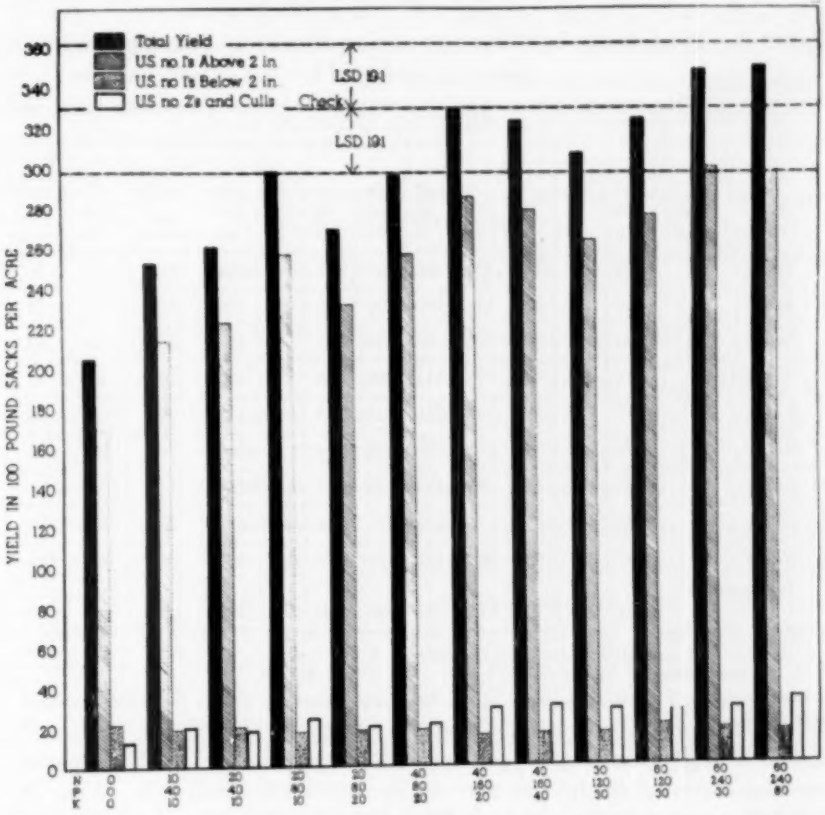

FIG. 3—The effect of fertilizer on the color of Red McClure potatoes in the San Luis Valley 1946-1949

L. S. D. Years— 1 Per cent = 0.1

The colors used were Muncella Color Company's 104R8/6 and 2.5R4/10. These colors closely approximated Light Pinkish Cinnamon and Eugenia Red, respectively, as listed in Ridgeway's Color Standards and Nomenclature.

a difference in cultural practices, differences in the size and amount of seed used, and also in the distance between rows. Consequently no L.S.D. was calculated for difference between farms.

The trend on different farms was similar, although the interaction between

fertilizers and farms was highly significant both years, indicating a differential response. Nine treatments of six replications each were completed on nine farms in 1948 and on eight farms in 1949. The mean for each treatment was derived from 54 units in 1948 and 48 units in 1949. The coefficient of variability was 11 per cent. Consequently it appears that considerable reliance can be attached to the data.

In 1948 (Table 2) 20 pounds of N, 80 pounds of available P_2O_5 and 20

TABLE 2.—*Total yields in 100-pound sacks per acre of fertilizer trials on farmer's fields 1948*

	(Treatments in pounds per acre of available nutrients)											
										Mean	L. S. D.	
	N	0	20	0	0	20	20	40	40	40	Yield	5	1
Soil	P_2O_5	0	0	80	0	80	80	80	160	160	per	Per	Per
Texture	K_2O	0	0	0	20	0	20	20	20	40	Farm	cent	cent
1. Sandy		292	259	309	239	346	320	335	398	361	318	56	75
2. Sandy		123	191	122	121	196	200	236	255	246	188	27	21
3. Sandy		296	305	303	273	340	332	329	388	364	326	34	45
4. Sandy Loam		178	245	201	194	244	268	263	293	292	242	26	35
5. Loam		177	184	157	194	263	234	243	287	242	220	67	89
6. Loam		135	147	168	151	175	188	172	201	202	171	38	49
7. Loam		100	128	133	93	135	144	141	168	203	149	45	61
8. Sandy Clay		248	276	287	276	320	337	372	379	389	320	57	76
9. Heavy Clay		282	317	330	302	313	326	317	348	327	318	NS	NS
Treatment Means		203	228	223	227	259	261	268	302	292	252		

L. S. D. for comparing treatments means combining all farms— 5 Per cent = 14
1 Per cent = 18

Soil textures, 1-8 inclusive, were in the San Luis Valley; 9 was in Northern Colorado near Greeley.

pounds of K_2O when used separately produced increases in yield, compared with the untreated check, that were highly significant statistically. When N and P_2O_5 were applied together at 20 and 80 pounds per acre, respectively, the increased yield compared with any of the three elements used alone was highly significant. However, there was no significant increase in yield when K_2O at 20 pounds per acre was added to the N and P_2O_5. This is not easy to explain in view of the fact that K_2O alone gave a significant increase in yield.

When P_2O_5 and K_2O were held at 80 and 20 pounds per acre, respectively, and N was increased from 20 to 40 pounds the yield increase was not great enough to be significant at odds of 19-1. When N and K_2O were held at 40

and 20 pounds, respectively, and P_2O_5 was increased from 80 to 160 pounds the yield increased from 270 to 302 sacks per acre, a highly significant increase statistically. When N was held at 40 pounds and P_2O_5 at 160 pounds, and K_2O was increased from 20 to 40 pounds a statistically non-significant decrease in yield resulted.

The data from the 1948 trial indicated: (a) that increased yield from the use of potash was questionable, (b) that the amounts of fertilizer applied per acre were not high enough and (c) that the effect of using the fertilizer ingredients singly at larger amounts was not known. Consequently the same procedure used in 1948 was used in 1949 but the rates were doubled. The results are shown in table 3.

TABLE 3.—*Total yields in 100-pound sacks per acre of fertilizer trials on farmer's fields 1949.*

(Treatments in pounds per acre of available nutrients)

Soil Texture	N	0	40	0	40	40	40	60	60	60	Mean Yield per Farm	L. S. D. 5 Per cent	L. S. D. 1 Per cent
	P_2O_5	0	0	160	160	160	160	160	240	240			
	K_2O	0	0	0	0	20	40	40	40	60			
1. Sandy		147	198	167	208	235	250	262	262	261	221	29	29
2. Sandy		198	207	243	292	281	330	304	337	313	278	55	73
3. Sandy		264	290	284	357	366	362	368	399	382	341	35	47
4. Gravelly Loam		273	267	307	338	352	324	319	348	329	317	24	31
5. Gravelly Loam		233	340	277	331	371	366	374	395	386	341	68	91
6. Gravelly Loam		309	368	302	413	432	406	432	413	445	391	31	41
7. Loam		238	232	236	255	264	248	270	281	267	255	20	26
8. Clay Loam		178	198	178	214	209	234	220	223	227	209	5	6
Treatment Means		230	263	249	301	314	315	319	332	326	294		

L. S. D.— 5 Per cent = 13.3
1 Per cent = 17.5

Soil textures 1-6 were in the San Luis Valley, 7 was at Carbondale, and 8 in Weld County, Colorado.

As was the case in 1948 both N and P_2O_5 when used alone gave yields which were significantly greater than those produced by the unfertilized check. The treatments containing only K_2O were omitted in 1949 and a 40-160-0 treatment was added. This made it possible to put the experiment between two sub-ditches with adequate buffering where subirrigation was used.

N and P_2O_5 combined gave a much greater increase in yield than did either

element used alone. When N was added at the 40-pound level and P_2O_5 at the 160-pound level the addition of 20 pounds of K_2O caused an increase in yield almost significant at the 5 per cent point. When K_2O was increased to 40 pounds no further increase or decrease resulted. With P_2O_5 at 160 pounds and K_2O at 40 pounds, increasing N from 40 to 60 pounds resulted in a non-significant increase in yield. Maintaining N at 60 pounds and K_2O at 40 pounds and increasing P_2O_5 from 160 to 240 pounds resulted in an increase in yield which was almost significant at the 5 per cent point. When the K_2O level was increased from 40 to 60 pounds a non-significant decrease in yield was obtained.

Summary and Conclusions

Fertilizer studies, using the components N, P_2O_5 and K_2O singly and in various combinations on potatoes were completed on 17 farms over a two-year period and on the San Luis Valley Branch Station where a permanent plot design was used over a four-year period. The experiment was so designed that when one nutrient was varied the other two were held constant.

In general, potato yields were markedly increased by the use of commercial fertilizers. In 1948 the average increase in yield per acre caused by fertilization was 85 sacks; in 1949, 84 sacks.

The major increases in yield resulted from the use of N and P_2O_5 at the rates of 40 and 160 pounds per acre (40-160-0), respectively.

The increase in yield attributable to potash is questionable. On certain farms, when used at comparatively low rates (20 pounds K_2O per acre) beneficial results may occur.

The color, grade and specific gravity of the tubers were influenced less by the fertilizer used than by the differences in environmental factors between growing seasons.

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INSECTICIDE EXPERIMENTS ON POTATOES IN MINNESOTA DURING 1949.[1,2]

ALLAN G. PETERSON
University of Minnesota, St. Paul, Minn.

(Accepted for publication, June 8, 1950)

Although the effectiveness of DDT against most potato insects has made it a standard insecticide for potatoes, the control of aphids still presents a serious problem to the grower of certified seed in Minnesota. Observations during the past few years indicate that *Myzus persicae* (Sulzer) and *Macrosiphum solanifolii* (Ashm.), which are the most important aphids on potatoes in Minnesota, first appear on potatoes in late June or early July. The aphid populations frequently increase in early July, decrease during late July and early August, but increase to a second peak of abundance during late August and early September shortly before the vines reach maturity. Leafroll and mosaic viruses transmitted early in the season will usually produce symptoms by the time inspections for certification are made. However, plants infected late in the season may not develop symptoms prior to maturity, and such transmission may not become evident until field samples are grown in the Florida tests. The present experiments were designed primarily for comparing the aphicidal properties of several different formulations. The materials were also evaluated for the control of other insects injurious to potatoes.

Commercial scale experiments were conducted in the Red River Valley on a 17-acre field of Red Pontiacs grown by Mr. Arnold Amundson near Climax, Minnesota, and on an 18-acre field of Pontiacs grown by Mr. W. J. Koppen near East Grand Forks, Minnesota. Small scale hand-dusted and hand-sprayed plots of the Waseca variety were located at the North Central Experiment Station, Grand Rapids, Minnesota. At each location a standard 5 per cent DDT dust was used as a control with which other formulations were compared. Insect populations were sampled periodically in each plot by making several counts of insects per 10 leaves and several counts of insects per 25 sweeps of a standard insect net. The percentage of fleabeetle foliage injury was estimated periodically in each plot by a comparison of leaves selected at random with a diagrammatic chart. Yields were estimated on the commercial fields by digging two samples, each 2 rows wide by 2 rods long, from the center rows of each plot.

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[1] Paper No. 2563 Scientific Journal Series, Minnesota Agricultural Experiment Station.

[2] Cooperation of Agsco Chemicals, Inc., Grand Forks, North Dakota, and Division of Seed Certification, Minnesota State Department of Agriculture is gratefully acknowledged.

Amundson Field

Four materials were applied at the Amundson field with three replications. Each plot was 12 rows wide by 110 rods long (1.50 acres). The following formulations were used:

D5—DDT 5 per cent plus *Dithane** 6 per cent.

D5S2—DDT 5 per cent plus *Sovacide* 544F oil** 2 per cent plus *Dithane* 6 per cent.

P1—Parathion 1 per cent plus *Dithane* 6 per cent.

D5P1—DDT 5 per cent plus parathion 1 per cent plus *Dithane* 6 per cent.

Five applications of these dusts were made with a 6-row Niagara duster on the 30th of June; the 13th and 26th of July; and on the 5th and 22nd of August. Rates of application were 15, 20, 25, 30, and 30 pounds per acre, respectively.

Shortly after the first application a few transient aphids appeared, but species of aphids which normally occur on the potato crop remained scarce throughout the season and were never sufficiently abundant to permit an evaluation of the insecticides.

All four combinations appeared to give fair to good control of flea beetles (Table 1.) Although P1 had the highest flea beetle counts in most cases, this difference was not significant. Similarly, differences in percentages of flea beetle foliage injury did not reach the level of significance. However, flea beetle foliage injury appeared to be associated with population counts, and parathion plots had the highest percentage of foliage injury.

Table 1.—*Average fleabeetle counts and percentage of foliage injury*

Dust	Pre-Dust 6/30	2 Days After 1st Appl. 7/2	10 Days After 3rd. 8/4	1 Day After 4th 8/6	10 Days After 5th 9/1	Average
Flea Beetles per 25 Sweeps						
D5	29.7	0	65.3	16.2	0.5	20.5
D5S2		0.2	78.3	20.3	1.0	25.9
P1		0.7	125.3	6.0	7.5	34.9
D5P1		0	51.0	1.3	0.7	13.3
Differences not Significant						
Per cent Flea Beetle Foliage Injury						
D5	6.7	.....	2.7	2.1	2.8	2.5
D5S2		.....	2.5	2.4	3.1	2.7
P1		.....	2.9	2.6	3.9	3.1
D5P1		.....	2.7	1.7	3.1	2.5
Differences not Significant						

* Product of Rohm and Haas.

** Product of Socony-Vacuum Oil Co.

The potato leafhopper, *Empoasca fabae*, although moderately abundant in the vicinity, was held to low numbers by all four materials, and no significant differences occurred among populations of this insect.

Macrosteles divisus, the six-spotted leafhopper, became fairly abundant in early July and again during the early part of September. In the count made on the July 2nd the insecticides containing DDT appeared to be somewhat more effective than parathion against this insect (Table 2), although the differences did not reach the level of significance. Data recorded on the 1st of September revealed that the formulations containing DDT gave significantly better control than parathion.

TABLE 2.—*Average counts of Macrosteles divisus per 25 sweeps.*

Dust	Pre-dust 6/30	2 Days After 1st Appl. 7/2	10 Days After 3rd. 8/4	1 Day After 5th 8/6	10 Days After 5th 9/1
D5	2.2	6.0	0	0	6.3
D5S2		4.8	0	0.5	7.2
P1		10.7	0	0	11.7
D5P1		6.2	0	0.7	7.3
Significant difference .05		....[1]			3.2
.01		....			4.8

[1] Differences not significant.

Since insect populations during the season were quite similar under the different treatments, it is not surprising to find that the yields showed no significant differences (Table 3).

TABLE 3.—*Average yields, Amundson Field.*

Dust	Average Yield Bushels per Acre
D5	435.0
D5S2	449.3
P1	444.9
D5P1	453.3

Differences not significant.

KOPPEN FIELD

Five formulations were applied at the Koppen field with 3 replications. Each plot was 12 rows wide by 80 rods long (1.09 acres). The following formulations were used:

D5—DDT 5 per cent plus *Dithane* 6 per cent.

D5SF—DDT 5 per cent plus *Sovacide* 544F oil* 1 per cent plus *Dithane* 6 per cent.

D5S1—DDT 5 per cent plus *Sovaspray* oil No. 1* 1 per cent plus *Dithane* 6 per cent.

D5S3—DDT 5 per cent plus *Sovaspray* oil No. 3* 1 per cent plus *Dithane* 6 per cent.

P1—Parathion 1 per cent plus *Dithane* 6 per cent.

Wet weather delayed the first application until it was necessary for the grower to hire a plane to dust the entire field with DDT in order to prevent extensive injury by Colorado potato beetles. After the airplane application of DDT on the 5th of July, five applications of the experimental materials were made with a 6-row Iron Age duster on the 9th, 16th, and 25th of July, and on the 4th and 20th of August. Rates of application were 15, 20, 25, 30, and 30 pounds per acre, respectively.

Aphids remained scarce throughout the season. Although occasional winged individuals of both the potato aphid, *Macrosiphum solanifolii*, and the green peach aphid, *Myzus persicae*, were found, the conditions were apparently unfavorable for the establishment of aphid colonies on potato. No evaluation of the materials was possible. Virus readings were made in the experimental plots on the 6th of August by Mr. G. M. Stromsmoe, Inspector for the Division of Seed Potato Certification. No current transmission of viruses was evident in any of the plots, and no significant differences existed in the incidence of leafroll and mosaic.

Some interesting results were obtained in the control of flea beetles, which were very abundant at the time of the 9-day count following the third application of dust. The four materials containing DDT showed significantly lower flea beetle populations than parathion (Table 4). Both D5S1 and D5SF had lower counts than D5, but these differences were not significant. However, D5S1 and D5SF did have significantly lower counts than did D5S3.

Flea beetle foliage injury was consistently greater in the plots treated with parathion than in those treated with DDT (Table 4). When average percentages of injury observed on the different dates were combined in an analysis of variance, D5S1 was found to have a significantly lower percentage of injury than D5, D5S3, or P1. These results might indicate that *Sovaspray* No. 1 prolonged the action of DDT whereas *Sovaspray* No. 3 reduced the residual properties. The apparent increase in effectiveness of DDT against flea beetles by the addition of *Sovaspray* No. 1 oil should be verified by further investigation.

* Products of Socony-Vacuum Oil Co.

TABLE 4.—*Average flea beetle counts and estimates of foliage injury.*

Dust	Pre-dust 6/29	9 Days After 3rd Appl. 8/3	1 Day After 4th 8/6	11 Days After 5th 8/31	Average
Flea Beetles per 25 Sweeps:					
D5	27.8	459.3	2.7	0	
D5SF		377.7	4.7	0	
D5S1		360.7	1.7	0	
D5S3		663.0	2.2	0	
P1		939.3	1.8	0.5	
Significant difference .05		274.4	....[1]		
.01		399.2	....		

Percentages of Flea Beetle Foliage Injury:

D5	5.8	1.5	2.4	4.1	2.7
D5SF		1.4	2.1	3.1	2.2
D5S1		1.2	1.8	3.0	2.0
D5S3		1.7	2.5	3.6	2.6
P1		3.2	3.2	5.5	3.9
Significant difference .05		....[1]	....[1]	....[1]	0.58
.01		....	....	....	0.84

Satisfactory control of *Empoasca fabae*, the potato leafhopper, was obtained with all formulations.

Parathion 1 per cent was relatively ineffective against the six-spotted leafhopper, *Macrosteles divisus* (Table 5). D5S1 had a significantly lower population of this insect than either D5S3 or P1 in the final count. In the earlier counts D5S1 did not seem particularly effective.

TABLE 5.—*Average counts of Macrosteles divisus per 25 sweeps.*

Dust	Pre-dust 6/29	9 Days After 3rd Appl. 8/3	1 Day After 4th 8/6	11 Days After 5th 8/31
D5	6.8	3.3	1.7	1.7
D5SF		4.5	2.2	2.3
D5S1		7.3	2.3	1.2
D5S3		6.2	1.3	2.8
P1		7.8	1.3	7.7
Significant difference .05		....[1]		1.5
.01		....		2.2

[1] Differences not significant.

Yield differences among the treatments were not significant, but a slightly lower yield was indicated for parathion than for insecticides containing DDT (Table 6).

TABLE 6.—*Average yields, Koppen field.*

Dust	Yield Bushels per Acre
D5	426.1
D5SF	442.7
D5S1	427.3
D5S3	448.1
P1	398.1

Differences not significant.

GRAND RAPIDS PLOTS

Small plots, 3 rows wide by 14 hills long, were staked out for 8 treatments with 3 replications in a field of Wasecas at the North Central Experiment Station, Grand Rapids, Minnesota. Preliminary trials with several new insecticides and different formulations containing DDT were used in this experiment as indicated below:

D5—DDT 5 per cent plus *Dithane* 6 per cent plus pyrax.

D5S—DDT 5 per cent plus *Dithane* 6 per cent plus dusting sulphur.

D5LS—DDT 5 per cent plus *Dithane* 6 per cent plus lime sulphur 5 per cent plus pyrax.

D5S4—DDT 5 per cent plus *Dithane* 6 per cent plus Sovaspray No. 4. oil 1 per cent plus pyrax.

DW—Spray containing DDT wettable powder and *Dithane* (one pound actual DDT and one pound Dithane per 100 gal.)

DE—Spray containing DDT emulsion and *Dithane* (one pound actual DDT and one pound *Dithane* per 100 gal.)

118—Aldrin 1 per cent plus *Dithane* 6 per cent plus pyrax.

497—Dieldrin 1 per cent plus *Dithane* 6 per cent plus pyrax.

Growth of the plants was slow because of excessive rainfall, and the first application of dusts and sprays was not applied until the 13th of July. A second application was made on the 28th of July. The applications of *Dithane* at 2-week intervals were inadequate for control of early blight which caused extensive injury to the susceptible Wasecas. Injury by the potato leafhopper was also severe in control plots and those dusted with aldrin and dieldrin. As the result of a misunderstanding, all experimental plots were sprayed with DDT on the 8th of August at the time the adjacent field was sprayed. A third application of experimental materials was applied as scheduled on the 11th of August, but insect population differences were no longer evident

in the various plots. The vines soon succumbed to water injury and early blight. Yields were not taken in this field because of the adverse conditions and the unfortunate application of DDT to all experimental plots.

Aphids did not become sufficiently abundant to permit an evaluation of the different formulations until late in the season when the vines were nearly dead as a result of combined injuries by excessive water, early blight, and potato leafhoppers. The late-season increase in the aphid population may have been responsible for the noticeable increase in virus content of potatoes grown in the vicinity as indicated by the Florida tests.

All of the materials proved effective against the Colorado potato beetle. This insect was quite abundant prior to the first application of dusts and sprays. Neighboring potato fields were partially defoliated before weather conditions permitted initial applications of insecticides.

Both aldrin and dieldrin were relatively ineffective against *Empoasca fabae* when applied as 1 per cent dusts. Although they produced a fairly good initial kill, they were lacking in residual effect (Table 7). No significant differences existed among leafhopper populations occurring with the other formulations all of which contained DDT.

TABLE 7.—*Average Empoasa fabae per 10 leaves, Grand Rapids.*

Insecticide	Pre-treatment 7/12	1 Day After 1st Appl. 7/14	14 Days After 1st 7/27	13 Days After 3rd 8/24[1]
D5	63.0	0	15.3	1.3[1]
D5S		0	12.3	0
D5LS		0	10.0	0.3
D5S4		1.0	13.3	2.3
DW		0	8.7	0.3
DE		0	4.3	0
118		4.3	91.7	1.0
497		3.3	88.0	2.3
Significant difference	.05		24.5	
	.01		34.0	

[1] All plots were sprayed accidentally with DDT on the 8th of August.

DISCUSSION

These experiments were designed to compare the aphicidal effectiveness of different formulations of DDT and several new insecticides with a standard 5 per cent DDT dust and 1 per cent parathion, the latter of which had previously proven effective against potato aphids in Minnesota. In all three locations the aphid populations failed to build up sufficiently to permit evaluation of

the insecticides. In view of the fact that most of the formulations performed favorably in comparison with the standard DDT, it is indeed unfortunate that more information could not be obtained regarding their effectiveness against aphids.

Although standard formulations of DDT have given fairly satisfactory control of potato flea beetles, it is apparent that the addition of a 1 per cent *Sovaspray* No. 1 oil to DDT dust may be somewhat superior to DDT alone. This should be confirmed in further trials and the efficacy of the material against aphids evaluated. The use of a heavier *Sovaspray* No. 3 oil apparently reduced the efficiency of the DDT. Parathion 1 per cent was inferior to DDT in the control of flea beetles.

Data from the Koppen field were suitable for some analysis of variance and co-variance studies which were made in order to investigate the relation of flea beetle populations to per cent foliage injury and their influence on yields. A close correlation existed between the large flea beetle populations on the 3rd of August and average percentages of foliage injury ($r=0.872$; 1 per cent level of significance=0.641). A low but significant negative correlation existed between flea beetle populations on the 3rd of August and yields ($r=-0.582$; 5 per cent level of significance=0.514). A similar negative correlation existed between average percentages of foliage injury by flea beetles and yields ($r=-0.609$; 5 per cent level of significance=0.514).

As observed in previous years in Minnesota, parathion 1 per cent was not so effective as DDT in controlling *Macrosteles divisus*. Relatively heavy applications of DDT are apparently necessary for the control of this insect.

All formulations containing DDT were effective in controlling *Empoasca fabae*. Although parathion compared favorably with DDT in controlling small populations of this insect in the Red River Valley, it was observed in 1948 that 1 per cent parathion dust was much inferior to 5 per cent DDT dust in controlling heavier infestations of potato leafhoppers at University Farm and Grand Rapids, Minnesota. Because of their inferior performance against the potato leafhopper, aldrin and dieldrin can not be considered promising insecticides for potatoes in Minnesota. It is possible, of course, that they might be useful in combinations with DDT if they should prove superior in the control of aphids.

FURTHER STUDIES ON COPPER SULPHATE-LIME RATIOS IN BORDEAUX MIXTURE[1]

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Studies on the effects of varying the proportion of lime in Bordeaux mixture for potato spraying were begun in 1943 at the Dominion Laboratory of Plant Pathology at Charlottetown, Prince Edward Island. The results obtained during the first four years of the investigations have already been published (3). The present paper gives the results obtained in a continuation of the studies in 1947 and 1948.

The formulae for the Bordeaux mixtures employed in this experiment were: 4-4-40, 4-3-40, 4-2-20, 4-1-40.[3] The formula 4-4-40 had been used for many years but, as a result of these tests, all growers in the province who have continued to use Bordeaux mixture for the control of potato late blight have reduced the lime content to one-half the amount formerly recommended, and the formula 4-2-40, is now the accepted one. The chief advantages of the 4-2-40 over the 4-4-40 formula are that the mixture rarely clogs the sprayer nozzles, controls late blight more effectively, favors higher yields, and leaves less lime on the plants.

One of the undesirable features of Bordeaux spray is the prominent residue which makes it difficult to detect virus-infected plants, especially those affected with the various types of mosaic. It has been apparent, however, that the intensity of the spray residue, and consequently its masking effect on mosaic leaf symptoms, decreases regularly as the ratio of copper sulphate to lime is changed in the order 4-4-40, 4-3-40, 4-2-40, but, contrary to what might be expected, the intensity is most pronounced on foliage treated with the 4-1-40 mixture. The differences in the intensity of the residues are probably correlated with the chemical composition of the precipitates formed by the reaction of copper sulphate and calcium hydroxide. Pickering (9,10) suggested that the chemical composition of the precipitate depended upon the proportion of lime, and concluded that a series of basic salts were produced. This view was supported by Martin (8). According to Pickering (9, 10), the precipitated

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[3] Forty Imperial gallons—equivalent to fifty U. S. A. gallons.

salts ranged from basic copper sulphates to basic copper-calcium sulphates as the proportion of lime was increased.

Studies on the pH values of the Bordeaux mixtures used in the experiments at Charlottetown were made in 1946, 1947, and 1948. Each time a mixture was prepared a sample was taken from the sprayer tank and filtered, and the pH of the filtrate was determined with a Beckman pH meter. The filtrates of the 4-1-40 mixture invariably showed a slight acid reaction, although filtrates of similar mixtures prepared in the laboratory with fresh reagent chemicals were slightly alkaline (Table 1). These results indicated

TABLE 1.— *pH values of Bordeaux mixtures at 20°C.*

Bordeaux Formulae	Field Mixtures			Mean	Laboratory[1] Mixtures
	1946	1947	1948		
4-1-40	6.20	6.51	6.54	6.43	7.24
4-2-40	11.60	11.81	11.84	11.75	11.81
4-3-40	12.19	12.14	12.02	12.12	12.20
4-4-40	12.35	12.24	12.12	12.24	12.26

[1] Prepared with fresh laboratory chemicals and distilled water.

that the commercial hydrated lime used in the preparation of the field mixtures did not furnish sufficient calcium hydroxide to react with all the copper sulphate. The hydrogen ions released by the partial hydrolysis of free copper sulphate might account for the acid reaction of the 4-1-40 field mixture filtrates.

Increased yields resulting from the adoption of low-lime Bordeaux mixtures have been reported by Mader (7), Blodgett *et al* (1), Bonde (2), and Callbeck (3). Lutman (6) has shown that lime has a tendency to dwarf the plants, and Bonde (2) noted that dwarfing of potato plants decreases as the lime content of Bordeaux mixture is reduced. Horsfall and Suit (4) have shown that lime is deleterious to certain vegetables, including potatoes. Both Lutman (6) and Blodgett (1) concluded that copper was the stimulatory agent, but Horsfall and Turner (5) suggested that it was more likely that lime injury was reduced as the lime was decreased.

RESULTS FOR 1947

In 1947, the treatments were arranged in two adjacent and parallel Latin squares and the plots were planted on the 23rd of May. The same variety, Green Mountain, was used in this year as it was in the other years of the investigation. The sprays were applied on the 14th and 24th of July, on the 5th, 15th and 26th of August, and on the 4th and 16th of September, with a tractor-sprayer unit—power take-off type having four nozzles per row—that

maintained a pressure of 300 pounds. Complete coverage of the foliage was reasonably well assured by driving the sprayer both up and down the rows each day the applications were made. For insect control, 50 W DDT at the rate of 0.75 pounds per 40 Imperial gallons was added to all mixtures. The check plots were treated with this insecticide alone on the same days that the Bordeaux mixtures were applied.

July and August were unusually dry months, temperatures were high—the mean temperature for July being the highest ever recorded in Prince Edward Island for the month—and consequently meteorological conditions were not favorable for the development of late blight. During August and September, the plants were sprinkled with a water suspension of spores of the fungus *(Phytophthora infestants* (Mont.) de Bary), but almost no infection was present on them until shortly before they were severely damaged by frosts in the last week of September.

The plots were harvested on the 6th of October, and the tubers, after a 4-week period in common storage, were weighed, graded, and examined for late blight rot. It was found that the amount of late blight rot was less than 1.0 per cent for each of the four Bordeaux treatments, whereas the check plots suffered a loss of 8.0 per cent of their total yield. The yield, however, of the check plots was not much below the yields of the sprayed plots. This was the first year of the investigation in which the yield of the check plots so nearly approached the yields of the Bordeaux treated plots. The mean difference between the yields of the treated and untreated plots was only 9.5 bushels per acre in 1947, whereas in 1945, 1946, and 1948, the mean differences were 24.8, 35.7, and 97.1 bushels per acre, respectively. The late and very brief period of the blight outbreak probably accounted for the very slight difference in the yields of the treated and untreated plots in 1947. The highest yields in 1947 were produced by the plots that received the Bordeaux mixture prepared according to the formula 4-2-40 (Table 2).

TABLE 2.—*Effect of copper sulphate-lime ratio on yield of potatoes.*

Bordeaux Formulae	Yields in Bushels per Acre		
	1947[1]	1948[2]	Mean
4-1-40	325.6	300.5	313.0
4-2-40	340.2	310.9	325.5
4-3-40	326.8	299.5	313.1
4-4-40	335.6	301.2	318.4
Check	322.5	205.9	264.2

[1] Very light foliage infection late in season. Differences not significant.

[2] Severe epiphytotic in 1948. Least significant difference at the 5 per cent level = 27.07 bushels per acre; at the 1 per cent level = 40.06 bushels per acre.

Results for 1948

The treatments in 1948 were arranged in the same manner as in 1947, that is to say, in two parallel Latin squares, and the planting was made on the 3rd of June. The sprays were applied on the 19th and 29th of July, and the 9th 19th and 30th of August, and on the 8th and 15th of September, the methods and technique being similar to those used in 1947.

Ideal conditions for the development of a late blight epiphytotic prevailed throughout the season, the period being characterized by frequent showers, regular dews, high humidity, and moderate temperatures. During the first two weeks of August, the plots were sprinkled four times with water suspensions of late blight spores. These disseminations, coinciding with periods of showers, effectively initiated infection. The disease was well established on the plants in the untreated plots by the 23rd of August and before mid-September they were completely defoliated. On the 28th of September, the plants were killed by spraying them with a sodium arsenite vine killer in order that harvesting could be undertaken before the advent of inclement weather.

The plots were harvested on the 6th of October, and the tubers, after a 4-week period in common storage, were weighed, graded, and examined for late blight rot. Each treatment resulted in yields significantly higher than the checks at both the 5 per cent and 1 per cent levels (Table 2), and, as in 1947, the highest yields were obtained from plots sprayed with the 4-2-40 Bordeaux mixture.

A review of the tuber rot data recorded during the course of these studies on copper sulphate-lime ratios in Bordeaux mixture shows that less rot has occurred in the plots treated with the 4-1-40 Bordeaux, and that the losses from blight rot increase as the ratio of lime to copper sulphate changes in the order 1:4, 2:4, 3:4, 4:4 (Table 3).

Table 3.—*Summary of losses from late blight tuber rot, 1943-1948.*

Bordeaux Formulae	Percentage of Total Weight Lost							
	1943	1944	1945	1946	1947	1948	Mean	Ratio
4-1-40	....	0.5	0.2	0.3	0.6	0.9	0.5	1
4-2-40	0.1	4.5	0.2	0.6	0.5	2.3	1.4	3
4-3-40	0.1	9.0	1.2	0.6	0.9	0.9	2.1	4
4-4-40	0.8	12.7	0.4	1.1	0.2	3.9	3.2	6
Check	0.8	23.8	6.4	16.0	8.0	7.5	10.4	21

Summary

Studies on the effects of varying the proportion of lime in Bordeaux mixture for potato spraying were started at Charlottetown, P.E.I., in 1943. This

is the second paper reporting on these studies and covers the work of 1947 and 1948. These two years were quite antithetic in respect to meteorological and disease conditions, yet, in both seasons, the highest yields were obtained from plots treated with Bordeaux mixture having a copper sulphate-lime ratio of 2:1. Late blight tuber rot data from 1943 to 1948, inclusive, indicate that a low-lime Bordeaux mixture is more effective than a high-lime one in controlling tuber rot, the ratio of losses from plots treated with 4-1-40, 4-2-40, 4-3-40, and 4-4-40 Bordeaux mixture being 1:3:4:6.

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IV. METHODS AND RESULTS OF BREEDING RESISTANT STRAINS OF POTATOES

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INTRODUCTION

On the basis of the investigations on resistance to late blight, viruses, and the potato beetle of cultivated varieties and wild species, systematic breeding for the resistance should have, from the beginning, used: (1) those species with the broadest range of resistance to all known races of late blight; (2) those which at the same time exhibit immunity to the virus diseases or at least one of them; and (3) those which are equally proved to be resistant to the Colorado beetle. Unhappily, the course of the researches in the different phenomena of the resistance was not that of temporary parallel results, but one of historic sequence. At first, species resistant to the then known races of *Phytophthora infestans* were analyzed and used in the breeding program, above all *Solanum demissum utile*. Later on (1937/38) new more virulent races eliminated most of the forms of *S. demissum* and many of the strains selected from crossings and backcrossings with *S. tuberosum*.

When the few species resistant to all eight races had been recognized and a new crossing and selection program was based on them, research in virus disease resistance had not yet proceeded so far that its results could have been coordinated with the breeding program for resistance to late blight. The virus resistant species were not yet analyzed. Year after year strains selected for resistance to late blight had to be eliminated on account of their susceptibility to virus diseases. The whole breeding program was endangered until the resistant strains were cultivated in a relatively virus free district of Pommerania.

Resistance to the Colorado beetle is very complicated in itself and the selection of resistant strains is even more difficult. So it could not be hoped in the beginning to coordinate the breeding programs for resistance to late blight and to the beetle.

Under those circumstances the selection of late blight resistant strains had to go ahead. As soon as satisfactory strains had been obtained, they were to be used instead of susceptible varieties in the crossing and selection program with reference to virus diseases and the Colorado beetle.

[1] Director

1. The Breeding of Late Blight Resistant Strains

H. Lehmann (1938a) has reviewed the hazardous and often dramatic history of the selection of late blight resistant strains of potatoes. He established a new basis for the breeding program when he proved that only *S. demissum* El Desierto, *S. demissum tlaxpehualcoense*, *S. ajuscoense* and *S. polyadenium* possessed complete resistance to the then analyzed 8 physiological races of *Phytophthora infestans* (1934). In further investigations *S. dem.* Lindley 029 was recognized, too, as fully resistant. The same author proved that no strains resistant to the most virulent race 8 could be obtained from hybridization with species resistant only to races 1-7. Of the remaining resistant wild species, *S. ajuscoense* and *S. polyadenium* offered great obstacles in hybridization with *S. tuberosum*. Hybrids of *S. polyadenium* and *S. tuberosum* were obtained only in 1942 (Stelzner 1949), whereas no direct hybrids of *S. ajuscoense* and *S. tuberosum* have been obtained until now. Nevertheless, we succeeded in making a triple hybrid (*S. dem.* x *S. ajuscoense*) x *S. tuberosum* which should allow for the concentration of genes for resistance of both wild species in new strains.

In the breeding work with *S. dem. tlaxpehualcoense*, *S. demissum* El Desierto and *S. dem.* Lindley 029, the same observations were made as before with *S. dem. utile;* namely, the extreme difficulty, if not impossibility to select strains completely resistant to all 8 races in F_2, F_3, or F_4. After backcrossing the F_1 hybrids with varieties of *S. tuberosum* and continuing so with F_2 and F_3, the chromosome number of 60 in the F_1 is regulated down to 48. Since the genes for resistance are linked with genes for "wild" characters in the species, selection for cultivated characters in the F_2 and following generations must result in the production of plants which have eliminated the surplus chromosomes carrying genes for resistance. Actually selection was made giving preference to resistance. Notwithstanding, no strains could be obtained combining resistance to all races with all other requisites of a good strain. The exact genic basis of resistance to all 8 races of late blight is not known but is suspected to be polygenic. The logical conclusion is that a series of crossovers of genes for resistance must take place if the desired combinations of complete resistance to the 8 races, together with good characters of quantity and quality of yield, time of ripening, and morphological characteristics shall arise. Our experience has proved that only the production of very great numbers of seeds from systematic hybridization and backcrossings and the testing of great numbers of seedlings for resistance offered a sufficient chance for success. In 1937 from approximately 135,000 F_2 plants produced from several combinations of (*S. dem. utile* x *S. tuberosum*) x *S. tuberosum* only 85 could be selected as resistant after twofold infection with the eight races of *P. infestans* (Lehmann, 1938). From 1940 to 1944 about 500,000 seedlings have been produced yearly

from planned crossings and have been selected for resistance first, and later on in the nursery for other good characters.

Methods of Selection

For the handling of such great numbers of plants Lehmann and Stelzner (1939) developed the following method of inoculation: The young seedlings were inoculated in incubation chambers of special glass houses when the first leaves appeared with a suspension of a mixture of spores of the eight races. Temperatures were regulated at approximately 20-23°C., and the relative humidity was maintained at 90-100 per cent. The majority of susceptible plants died and the resistant seedlings could be selected. Six to seven days after the infection had appeared, they were transplanted into boxes and brought to hot-beds where they could be infected under glass and shadowing-covers a second time. The surviving plants were transplanted in paper pots in the nursery. The morphologically and otherwise promising seedlings were inoculated another time by placing cuttings in boxes with sand in the incubation chamber of the glass-houses. After this at harvest time, selection was effected on the basis of other than resistance qualities. During the winter time the final selection for resistance was made by means of inoculating 2 tubers per seedling according to the method of Lehmann (1938b).

In 1941, for example, following this method of selection, 40,000 resistant seedlings from F_2, F_3 and F_4 generations were planted in the nursery. Two thousand of these were tested in 1942 as clones and selected for resistance (cuttings), yield and quality. In 1944, of the 2000 clones, only 200 remained promising.

On account of the elimination of surplus chromosomes from F_1 to F_2, F_3 and F_4 most strains survived with only partial resistance to some of the eight races. It was concluded that different partially resistant strains would contain genes for resistant to different races. Therefore partially resistant strains were crossed with one another. During war-time it has not been experimentally proved which of the strains contained the complementary genes for resistance, but as a matter of fact the percentage of completely resistant seedlings (covering resistance to the eight races) has augmented considerably, so that about 25 per cent of the tested seedlings proved to be completely resistant in the years 1943 and 1944.

The greatest difficulty to overcome was and is the succumbence of the selected blight resistant clones with the other necessary good characters of a high yielding variety with good quality to the infection with viruses. Whereas in Eastern Germany virus Y had proved to be most dangerous, in western Germany the leafroll virus is really rapturous. There was no proved basis for resistance to viruses in the blight resistant wild species, nor in the varieties used in hybridization and backcrossings. Nevertheless, there could be ob-

served differences in time and grade of break-down by virus diseases, and selection was effected on this basis. We have obtained certain results after suffering very heavy losses of blight resistant clones year after year. In 1947, 3844 resistant clones were examined in yield trials. During the extremely hot and sunny summer, primary infection with the leafroll virus took place in an extraordinary measure. In 1948, despite the most vigorous elimination of all visibly infected plants in 1947, a complete break-down of 2280 clones had to be reported. The best of the remaining clones exhibit a grade of resistance such as varieties like Ackersegen, Aquila and Bona and offer a chance that some of them may be released as blight resistant varieties. The following list gives a survey of the elimination of clones selected for resistance to late blight during the years 1944 to 1948:

	Hohensee	Ebstorf		Scharnhorst	
	(Pommerania)	Lüneburger Heide (West. Germany)		Lüneburger Heide	
	1944	1945	1946	1947	1948
A-clones	8480	363	224	71	22
B-clones	280	170	16	10	2
C-clones and older	275	111	81	43	33

A-clone results from the original seedling; B- and C-clones are the vegetative generations following the A-clone.

Wart Resistance

In Germany, strains which are resistant to the wart disease only are admitted as new registered varieties. Testing for wart resistance is official and the methods are uniform. Pre-selection is effected by inoculating 3-5 tubers per clone. In the second test, 20 tubers are inoculated, and in the final decisive test 3 x 50 tubers per clone are tested. Generally, about 50 per cent of the selected blight-resistant clones must be eliminated because they are susceptible to wart. The percentage varies according to the varieties used in hybridization and backcrossing. Frequently very promising blight-resistant clones must be eliminated in the final stages because of their susceptibility to wart disease.

It is known that a new physiologic race of wart disease has been recognized (Giesshuebel)*. Up to the present, it has not yet been used in testing for resistance on account of war and post-war difficulties.

Time of Ripening and Blight Resistance

It has been proved by several authors (Kühn 1880, Müller 1928, Bakasov 1936, Lehmann 1938b) that early ripening varieties are generally more ex-

* A locality in Thuringia, where it occurred.

posed to late blight than late ripening varieties in certain parts of Europe because the most susceptible stage of development of early varieties concides with optimal conditions for infection with late blight. Notwithstanding the great need for early and medium early blight resistant varieties, the first promising resistant clones are medium late or late. Economically the later-ripening group of varieties is of greater importance, as they occupy a larger area. Since 1946 more attention has been paid to the selection of late blight resistant strains of early maturity. For this reason the most promising late resistant strains are crossed with early varieties such as Fruehmoelle, Erstling (Duke of York), Vera and Fruehbote. Our first promising results have been obtained.

The Use of Resistant Wild Species Other Than *S. demissum tlaxpehualcoense* and *S. demissum* El Desierto and *S. demissum* Lindley 029

It is a general principle in our breeding for resistance in cultivated plants not to build up resistant strains with only one and the same resistant parent. For this reason Lehmann and Stelzner have selected late blight resistant strains from the species *S. ajuscoense*, *S. verrucosum* and *S. antipoviczii*. Apart from that, Stelzner (1949) recognized, by means of artificial inoculation, that at least one such late blight resistant strain of *S. ajuscoense* and one strain of *S. antipoviczii* is immune to virus Y.

Hybridization with these strains was begun in 1942. Ross has reported above on the heredity of resistance to virus Y of the selected form of *S. antipoviczii* in hybrids. Inbreeding of the most promising clones resistant to late blight has been initiated in order to get inbreds homozygous for the resistance to late blight which will be used in this program.

The Coordination of Breeding for Resistance to Late Blight, to Virus Diseases, and to the Colorado Beetle

The information gained from investigations in the resistance behavior of the wild species at our disposal allows for a combined system of breeding. The simplest way is the use of late blight resistant clones for hybridization with species resistant to the beetle and to virus diseases instead of susceptible varieties. Thus, in the breeding for beetle resistance, the beetle resistant species and hybrids of *S. chacoense* and *S. polyadenium* are crossed and backcrossed with late blight resistant clones. In this way, combined resistance to late blight and to the beetle may be expected. The same principle is followed in building up virus resistant strains.

In several cases one wild species demonstrates combined resistance to more

than one parasite. The following table gives a survey on combined resistance in wild species.

	Phytophthora infestans	Virus				Colorado Beetle
		A	X	Y	Leafroll	
1. *S. demissum tlaxpehualcoense*	+	?	—	—	?	+
El Desierto	+	?	+	+	?	+
Lindley 029	+	?	?	?	?	+
2. *S. polyadenium*	+	?	—	+	—	+
3. *S. antipoviczii*	+	?	—	+	Tol.	+
4. *S. ajuscoense*	+	—	—	+	—	+
5. *S. verrucosum*	+	+?	—	+?	Tol.	+
6. *S. chacoense*	—	+?	—	+	Tol.	+

From this table it is clear that the following combinations of the three varieties of *S. demissum* would be advisable:

1. *S. dem.* (36) x *S. polydenium* (12)=F_1 (48)
2. *S. dem.* (36) x *S. ajuscoense* (12)=F_1 (48)
3. *S. dem.* (36) x *S. verrucosum* (12)=F_1 (48)
4. *S. dem.* (36) x *S. chacoense* (12)=F_1 (48)

Hybrids of No. 2 + 3 have been obtained and crossed with *S. tuberosum* or selfed. *S. antipoviczii* as a tetraploid species has been crossed with *S. tuberosum*, and it has been combined equally with *S. chacoense* 4n *S. polyadenium* has been hybridized with *S. chacoense* Siambon. As leafroll resistant seedlings have been analyzed up to the present time only within *S. chacoense*, they should be used to build up leafroll resistant strains. Some such combinations have already been mentioned.

Now that strains resulting from hybridization with *S. demissum* have been obtained that are resistant to late blight and possess the characteristics of good commercial varieties, they are used often instead of the late blight resistant *S. demissum* varieties. This offers a great advantage. It already has been indicated that the late blight resistant strains are used, too, for backcrossing. So we are proceeding in the following different ways to build up resistant varieties of potatoes:

1. The existing late blight resistant hybrid clones from *demissum* x *tuberosum* are used for hybridization and backcrossing with species resistant to the different virus diseases and to the Colorado beetle. In this way hybrid clones, resistant to late blight and different virus diseases, must finally be combined with equally late blight resistant clones resistant to the Colorado beetle, in order to get clones resistant to late blight, virus diseases and the Colorado beetle.

2. Wild species, with preference for those which exhibit combined resistance to several diseases and the beetle, are hybridized at the beginning in order to obtain hybrids with complete resistance to late blight, virus diseases, and the Colorado beetle. These complex hybrids, which are built up in such a manner that they contain 48 chromosomes, are then crossed with the already existing late blight resistant hybrid clones.

Actually the following complex hybrids with reference to resistance to late blight have been obtained and are used in the breeding program:

1. *S. demissum* 029 Buk. x *S. verrucosum* Schl. 570
2. *S. demissum* El Desierta Reddick 530 x *S. verrucosum* Schl. 570
3. *S. demissum* Rio Frio x *S. verrucosum* Schl. 570
4. *S. demissum tlaxpehualcoense* x *S. verrucosum* Schl. 570
5. *S. antipoviczii* x *S. Rybinii*
6. *S. demissum Kl.* x *S. Kesselbrennerii*
7. *S. demissum* x *S. Rybinii*
8. *S. demissum tlaxpehualcoense* x *S. Rybinii*
9. *S. antipoviczii* x *S. chacoense*
10. *S. demissum* x *S. chacoense* (both resistant to the Colorado beetle)

All these hybrids of wild species have been crossed once or twice with varieties of *S. tuberosum* or hybrid clones resistant to late blight.

The species *S. Rybinii* and *S. Kesselbrennerii* have been used for their field resistance to virus diseases, especially to virus Y in eastern Germany. The hybrids do not manifest marked resistance to leafroll in western Germany. Other hybrids, which were produced from different species are not cited because they have not yet been crossed and backcrossed with *S. tuberosum*. The following list contains some of the cited complex hybrids with their behavior towards late blight:

HYBRID	Number of Tested Clones	Resistant to 48/1	Eliminated	Resistant in Open Field	Resistant to Tuber Inf. with 4 Populations of Late Blight 1948/49	
(*S. dem* x *S. Rybinii*) x *S. tuberosum*	6	2	1	0		
(*S. dem. res* x *S. verr.*) x *S. tuberosum*	1	1	—	1	0	
(*S. dem, res.* x *S. verr.*) x *S. tub.* x *S. tub.*	5	3	—	3	0	
(*S. dem.* x *S. Rybinii*) x *S. tub.* x *S. tub.*	15	8	1	7	2	
(*S. Salamanii* Nr. 5010 x *S. tub.*) x *S. tub.*	10	6	4	2	1	
(*S. tub.* x *S. polyad. colch.*) x Aquila						
1948 foliage—Phyt. race 48/1	18	10	2	8		
1948/49 tubers—Mixture of					Foliage	Tubers
+foliage populations I-IV	7				7	3

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Paper reviewed by Dr. G. H. Rieman, University of Wisconsin, Madison, Wis.

SECTIONAL NOTES

Indiana

With all the unfavorable publicity concerning the potato crop and from what we read in one of the national weekly magazines, it appears that all potato growers are in the "dog house."

The entire early crop in southern Indiana has been harvested. The late crop looks very well, with no blight or leafhopper damage on the sprayed plots, and most of our growers have sprayed. All the early potatoes moved well—consumed at the local markets. In our main potato acreages of northern Indiana the potatoes are being harvested. They are moving slowly, and the quality is good. The yields are excellent, and our growers are digging and marketing only what they have orders for at this time. Some of the growers are putting them in storage with controlled temperature and moisture. A few of our growers are also pre-cooling potatoes, using pre-cooled trucks and cooled trucks in the transportation. They are doing an excellent job of grading, and it appears that we will be able to get rid of most of our potatoes at a fair price. I am quite sure that the potato growers themselves can work out a much better method than the one we now have in effect.—W. B. Ward.

Michigan

Michigan has just passed through the coldest and wettest August on record. Prospects are good for a large yield. However, Michigan acreage is lower than that of last year and only about one-half the acreage we had for the ten-year period of 1930-1940.

Prospects are good with the Certified Growers. The acreage is about the

same as last year with increases in both Katahdins and Sebagoes, the decline in acreage is with Russet Rural variety.

The situation in the early section, mostly the Bay City area, was anything but pleasing. Although the yields were good the prices were very disappointing. The movement was very slow with practically no government buying to help the situation.

Michigan growers will have a chance to vote on the Marketing Agreement the last week of September. This state has been under the Marketing Agreement for several years. The big question is, "Will it or will it not carry again this year?"

The Michigan Potato Growers' Exchange just completed its 32nd year's operation at its Annual Meeting on August 23rd. H. J. Evans of the New York Certified Seed Potato Growers' Co-operative Association was the principal speaker at the meeting using as his subject, "What the Potato Growers Can Do to Help Themselves."—H. A. Reiley.

New Jersey

The potato harvest in New Jersey has been slowed up a little by heavy rains, however, there is no fear yet of losing any because of freezing damage. Approximately 50 per cent of the crop has been harvested, whereas about 75 per cent had been harvested at this time in 1949.

The average yield is now estimated at 295 bushels per acre, the highest average ever reported for New Jersey. This high yield has resulted in an estimated production of 11,800,000 bushels compared with 10,137,000 bushels for the period 1939-'48. We will produce considerably more potatoes on the 44,000 acres grown this year than we did on an average of 62,000 acres grown during the 1939-'48 period.

Our small seed potato crop is developing very well and if we do not have an early frost a good yield is in prospect.—John C. Campbell.

New York

The New York potato crop looks fine. On the whole, we have had a good growing season, statistics show about a ten-year average crop almost close to maximum.

Special attention is being given to certified seed fields at the present time. Parathion has been used frequently to control insects and prevent spread of any virus. The incidence of virus disease has been very nominal and it looks as though our seed crop would be above par.

Growers have turned down Marketing Agreements decisively by a vote of 72.8 per cent No, and 27.2 per cent Yes. The negative vote represents about 63 per cent of the crop. This means that potato growers are willing to market their own crop and already several merchandising efforts are being organized. —H. J. Evans.

Washington

The seed potato acreage in Washington is about the same as was planted last year. Owing to a wet, late spring, most of the plantings were made at least a month later than usual, consequently we are expecting a reduction in yield. Some of the potatoes were planted on land that was too wet and consequently dried out later in the season.

Blight has been held in good control. Practically all the fields have passed their second inspection. They had one advantage this year in the fact that nearly all the fields were planted with excellent foundation seed, so very little roguing has been required. Their dusting program has kept the fields very free from aphids, so we are expecting a clean crop.

We have found no sign of ring rot in any of our certified fields, as yet.—Louis W. King.

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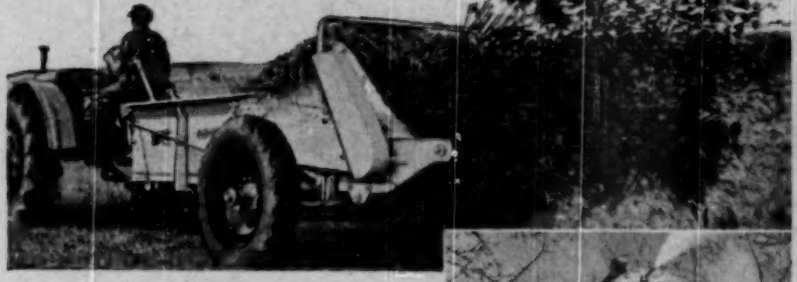

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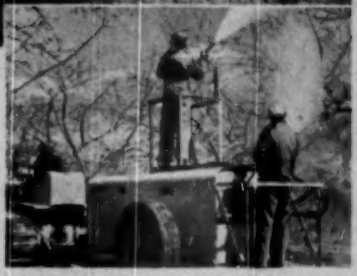

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